Amendments to the Claims

This listing of claims will replace all prior versions, and listings of claims in the application.

Listing of Claims:

1. (currently amended) A method of forming a cobalt silicide film, said method comprising:

forming a cobalt-containing film on a surface of a semiconductor substrate having an insulating region and a silicon-containing conductive region, the cobalt-containing film being formed at a temperature at which cobalt of the cobalt-containing film and silicon of the silicon-containing conductive region react with each other to form a diffusion restraint interface film interposed between the cobalt-containing film and silicon of the silicon-containing conductive region;

forming a titanium-rich capping film on the cobalt-containing film to obtain a resultant structure, the titanium-rich capping film having a titanium/other elements atomic% ratio of more than 1; and

annealing the resultant structure so that cobalt of the cobalt-containing film and silicon of the silicon-containing conductive region react with each other to form the cobalt silicide film.

2. (original) The method according to claim 1, wherein the capping film is one selected from the group consisting of a pure titanium film, a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen atomic%

ratio of less than 1, a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, and a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of less than 1.

3. (currently amended) The method according to claim ~~2~~ <u>1</u>, wherein the capping film is a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1.

4. (currently amended) The method according to claim ~~2~~ <u>1</u>, further comprising, before the formation of the cobalt-containing film, a pretreatment process of removing at least one of a natural oxide film and impurities formed on the silicon-containing conductive region.

5. (original) The method according to claim 4, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate; and

etching the wet-cleaned surface of the semiconductor substrate by radio frequency (RF) sputtering.

6. (original) The method according to claim 4, wherein the pretreatment process is devoid of radio frequency (RF) sputter etching.

7. (original) The method according to claim 6, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a hydrogen fluoride (HF) solution diluted with deionized (DI) water;

wet-cleaning the surface of a semiconductor substrate using a mixture solution of ammonium hydroxide, hydrogen peroxide (H_2O_2), and water; and

wet-cleaning the surface of a semiconductor substrate using a HF solution diluted with DI water.

8. (original) The method according to claim 6, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a mixture solution of sulfuric acid and H_2O_2; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

9. (currently amended) The method according to claim ~~2~~ 1, wherein the cobalt-containing film is a pure cobalt film, or a cobalt alloy film containing 20 or less atomic% of one selected from the group consisting of tantalum, zirconium, titanium, nickel, hafnium, tungsten, platinum, palladium, vanadium, niobium, and mixtures thereof.

10. (previously presented) The method of claim 1, wherein the cobalt-containing film is formed at a temperature range of 300-500°C.

11. (currently amended) The method according to claim ~~2~~ 1, wherein the annealing comprises:

primary rapid thermal annealing at a first temperature so that cobalt of the cobalt-containing film reacts with silicon of the silicon-containing conductive region to form a monocobalt monosilicide film;

selectively removing the capping film and the cobalt-containing film remaining unreacted during the primary rapid thermal annealing; and

secondary rapid thermal annealing at a second temperature which is higher than the first temperature so that the monocobalt monosilicide film is transformed into a monocobalt disilicide film.

12. (original) The method according to claim 11, wherein the first temperature is in the range of 350 to 650°C and the second temperature is in the range of 700 to 900°C.

13. (currently amended) A method of forming a cobalt silicide film, said method comprising:

forming a cobalt-containing film on a surface of a semiconductor substrate having an insulating region and a silicon-containing conductive region, the cobalt-containing film being formed at a temperature between 300 and 500°C at which cobalt of the cobalt-containing film and silicon of the silicon-containing conductive region react with each other to form a diffusion restraint interface film made of dicobalt monosilicide or monocobalt monosilicide interposed between the cobalt-containing film and silicon of the silicon-containing conductive region;

forming a titanium-rich capping film on the cobalt-containing film to obtain a resultant structure, the titanium-rich capping film having a titanium/other elements atomic% ratio of more than 1; and

annealing the resultant structure so that the diffusion restraint interface film is transformed into a monocobalt disilicide film, and cobalt of the cobalt-containing film reacts with silicon of the silicon-containing conductive region to form a monocobalt disilicide film.

14. (original) The method according to claim 13, wherein the capping film is one selected from the group consisting of a pure titanium film, a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen

atomic% ratio of less than 1, a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, and a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of less than 1.

15. (currently amended) The method according to claim ~~14~~ 13, wherein the capping film is a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1.

16. (currently amended) The method according to claim ~~14~~ 13, further comprising, before the formation of the cobalt-containing film, a pretreatment process of removing at least one of a natural oxide film and impurities formed on the silicon-containing conductive region.

17. (original) The method according to claim 16, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate; and

etching the wet-cleaned surface of the semiconductor substrate by radio frequency (RF) sputtering.

18. (original) The method according to claim 16, wherein the pretreatment process is devoid of radio frequency (RF) sputter etching.

19. (original) The method according to claim 18, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water;

wet-cleaning the surface of the semiconductor substrate using a mixture solution of ammonium hydroxide, H_2O_2, and water; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

20. (original) The method according to claim 18, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a mixture solution of sulfuric acid and H_2O_2; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

21. (currently amended) The method according to claim ~~14~~ 13, wherein the cobalt-containing film is a pure cobalt film, or a cobalt alloy film containing 20 or less atomic% of one selected from tantalum, zirconium, titanium, nickel, hafnium, tungsten, platinum, palladium, vanadium, niobium, and mixtures thereof.

22. (cancelled)

23. (currently amended) The method according to claim ~~14~~ 13, wherein the annealing comprises:

primary rapid thermal annealing at a first temperature so that the dicobalt monosilicide of the diffusion restraint interface film is transformed into monocobalt disilicide, and cobalt of the cobalt-containing film reacts with silicon of the silicon-containing conductive region to form a monocobalt monosilicide film;

selectively removing the capping film and the cobalt-containing film remaining unreacted during the primary rapid thermal annealing; and

secondary rapid thermal annealing at a second temperature which is higher than the first temperature so that the monocobalt monosilicide film is transformed into a monocobalt disilicide film.

24. (original) The method according to claim 23, wherein the first temperature is in the range of 350 to 650°C and the second temperature is in the range of 700 to 900°C.

25. (currently amended) A method of forming a cobalt silicide film, said method comprising:

wet-cleaning a surface of the semiconductor substrate having an insulating region and a silicon-containing conductive region;

forming a cobalt-containing film on the wet-cleaned silicon-containing conductive region, the cobalt-containing film being formed at a temperature between 300 and 500°C at which cobalt of the cobalt-containing film and silicon of the silicon-containing conductive region react with each other to form a diffusion restraint interface film made of dicobalt monosilicide or monocobalt monosilicide<u> interposed between the cobalt-containing film and silicon of the silicon-containing conductive region</u>;

forming, on the cobalt-containing film, a titanium-rich capping film with a titanium/other elements atomic% ratio of more than 1;

primary rapid thermal annealing at a first temperature so that dicobalt monosilicide of the diffusion restraint interface film is transformed into monocobalt monosilicide, and cobalt of the cobalt-containing film reacts with silicon of the silicon-containing conductive region to form a monocobalt monosilicide film;

selectively removing the capping film and the cobalt-containing film remaining unreacted in the primary rapid thermal annealing; and

secondary rapid thermal annealing at a second temperature which is higher than the first temperature so that the monocobalt monosilicide film is transformed into a monocobalt disilicide film.

26. (currently amended) A method of manufacturing a semiconductor device, the method comprising:

forming an isolation region defining an active region on a semiconductor substrate;

forming, on the active region, a source/drain region and a gate, the gate having a sidewall spacer and being made of polysilicon doped with impurities;

pretreating the source/drain region and the gate to remove at least one of the a natural oxide film and impurities;

forming a cobalt-containing film on a surface of the substrate at a temperature between 300-500°C at which cobalt of the cobalt-containing film and silicon of the substrate react with each other to form a diffusion restraint interface film interposed between the cobalt-containing film and the substrate;

forming a titanium-rich capping film on the cobalt-containing film to obtain a resultant structure, the titanium-rich capping film having a titanium/other elements atomic% ratio of more than 1; and

annealing the resultant structure so that cobalt of the cobalt-containing film and silicon of the gate and the source/drain region react with each other to form a cobalt silicide film.

27. (original) The method according to claim 26, wherein the capping film is one selected from the group consisting of a pure titanium film, a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a laminated structure of a

pure titanium film and a titanium nitride film having a titanium/nitrogen atomic% ratio of less than 1, a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, and a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of less than 1.

28. (currently amended) The method according to claim ~~27~~ 26, wherein the capping film is a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1.

29. (cancelled)

30. (previously presented) The method according to claim 26, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate; and

etching the wet-cleaned surface of semiconductor substrate by radio frequency (RF) sputtering.

31. (previously presented) The method according to claim 26, wherein the pretreatment process is devoid of radio frequency (RF) sputter etching.

32. (original) The method according to claim 31, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water;

wet-cleaning the surface of the semiconductor substrate using a mixture solution of ammonium hydroxide, H_2O_2, and water; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

33. (original) The method according to claim 31, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a mixture solution of sulfuric acid and H_2O_2; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

34. (currently amended) The method according to claim ~~27~~ 26, wherein the cobalt-containing film is a pure cobalt film, or a cobalt alloy film containing 20 or less atomic% of one selected from tantalum, zirconium, titanium, nickel, hafnium, tungsten, platinum, palladium, vanadium, niobium, and mixtures thereof.

35. (cancelled)

36. (currently amended) The method according to claim ~~27~~ 26, wherein the annealing comprises:

primary rapid thermal annealing at a first temperature so that cobalt of the cobalt-containing film reacts with silicon of the silicon-containing conductive region to form a monocobalt monosilicide film;

selectively removing the capping film and the cobalt-containing film remaining unreacted during the primary rapid thermal annealing; and

secondary rapid thermal annealing at a second temperature which is higher than the first temperature so that the monocobalt monosilicide film is transformed into a monocobalt disilicide film.

37. (original) The method according to claim 36, wherein the first temperature is in the range of 350 to 650°C and the second temperature is in the range of 700 to 900°C.

38. (currently amended) A method of manufacturing a semiconductor device, said method comprising:

forming an isolation region defining an active region on a semiconductor substrate;

forming, on the active region, a source/drain region and a gate, the gate having a sidewall spacer and being made of polysilicon doped with impurities;

forming a cobalt-containing film on a surface of the semiconductor substrate, the cobalt-containing film being formed at a temperature ~~between 300 and 500°C~~ at which cobalt of the cobalt-containing film and silicon of the source/drain region and the gate react with each other to form a diffusion restraint interface film made of dicobalt monosilicide or monocobalt monosilicide interposed between the cobalt-containing film and silicon of the source/drain region and the gate;

forming a titanium-rich capping film on the cobalt-containing film to obtain a resultant structure, the titanium-rich capping film having a titanium/other elements atomic% ratio of more than 1; and

annealing the resultant structure so that the diffusion restraint interface film is transformed into a monocobalt disilicide film, and cobalt of the cobalt-containing film reacts with silicon of the source/drain region and the gate to form a monocobalt disilicide film.

39. (original) The method according to claim 38, wherein the capping film is one selected from the group consisting of a pure titanium film, a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1,

a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1, a laminated structure of a pure titanium film and a titanium nitride film having a titanium/nitrogen atomic% ratio of less than 1, a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of more than 1, and a laminated structure of a pure titanium film and a titanium tungsten film having a titanium/tungsten atomic% ratio of less than 1.

40. (currently amended) The method according to claim ~~39~~ 38, wherein the capping film is a titanium nitride film having a titanium/nitrogen atomic% ratio of more than 1.

41. (currently amended) The method according to claim ~~39~~ 38, further comprising, before the formation of the cobalt-containing film, a pretreatment process of removing at least one of a natural oxide film and impurities formed on the source/drain region and the gate.

42. (original) The method according to claim 41, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate; and

etching the wet-cleaned surface of the semiconductor substrate by radio frequency (RF) sputtering.

43. (original) The method according to claim 41, wherein the pretreatment process is devoid of radio frequency (RF) sputter etching.

44. (original) The method according to claim 43, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water;

wet-cleaning the surface of the semiconductor substrate using a mixture solution of ammonium hydroxide, H_2O_2, and water; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

45. (original) The method according to claim 43, wherein the pretreatment process comprises:

wet-cleaning the surface of the semiconductor substrate using a mixture solution of sulfuric acid and H_2O_2; and

wet-cleaning the surface of the semiconductor substrate using a HF solution diluted with DI water.

46. (currently amended) The method according to claim ~~39~~ 38, wherein the cobalt-containing film is a pure cobalt film, or a cobalt alloy film containing 20 or less atomic% of one selected from tantalum, zirconium, titanium, nickel, hafnium, tungsten, platinum, palladium, vanadium, niobium, and mixtures thereof.

47. (cancelled)

48. (currently amended) The method according to claim ~~39~~ 38, wherein the annealing comprises:

primary rapid thermal annealing at a first temperature so that the dicobalt monosilicide of the diffusion restraint interface film is transformed into monocobalt monosilicide, and cobalt of the cobalt-containing film reacts with silicon of the source/drain region and the gate to form a monocobalt monosilicide film;

selectively removing the capping film and the cobalt-containing film remaining unreacted during the primary rapid thermal annealing; and

secondary rapid thermal annealing at a second temperature which is higher than the first temperature so that the monocobalt monosilicide film is transformed into a monocobalt disilicide film.

49. (original) The method according to claim 48, wherein the first temperature is in the range of 350 to 650°C and the second temperature is in the range of 700 to 900°C.

50. (currently amended) A method of manufacturing a semiconductor device, the method comprising:

forming an isolation region defining an active region on a semiconductor substrate;

forming, on the active region, a source/drain region and a gate, the gate having a sidewall spacer and being made of polysilicon doped with impurities;

wet-cleaning a surface of the semiconductor substrate;

forming a cobalt-containing film on the surface of the semiconductor substrate, the cobalt-containing film being formed at a temperature ~~between 300 and 500°C~~ at which cobalt of the cobalt-containing film and silicon of the source/drain region and the gate react with each other to form a diffusion restraint interface film made of dicobalt monosilicide or monocobalt monosilicide interposed between the cobalt-containing film and silicon of the source/drain region and the gate;

forming, on the cobalt-containing film, a titanium-rich capping film having a titanium/other elements atomic% ratio of more than 1;

primary rapid thermal annealing at a first temperature so that the diffusion restraint interface film is transformed into a monocobalt monosilicide

film, and cobalt of the cobalt-containing film reacts with silicon of the source/drain region and the gate to form a monocobalt monosilicide film;

selectively removing the capping film and the cobalt-containing film remaining unreacted during the primary rapid thermal annealing; and

secondary rapid thermal annealing at a second temperature which is higher than the first temperature so that the monocobalt monosilicide film is transformed into a monocobalt disilicide film.

51. (previously presented) The method according to claim 1, wherein the diffusion restraint interface film is made of dicobalt monosilicide or monocobalt monosilicide.

52. (new) The method of claim 38, wherein the cobalt-containing film is formed at a temperature range of 300-500°C.

53. (new) The method of claim 50, wherein the cobalt-containing film is formed at a temperature range of 300-500°C.